REMARKS/ARGUMENTS

This is in response to the Final Office action dated 09/15/2006 having a period of response to expire on December 15, 2006.

Rejection(s) under 35 USC §103

Claims 1-5, 9-11, 13, 21-28 are rejected under 35 U.S.C. 103(a) as being unpatentable over Hu et al. (US 6,660,627 B2) in view of Ference et al. (US 6,221,775 B1) in view of Morrow (US 6,872,666 B2).

The Invention, Generally

The invention is generally directed to maintaining uniform CMP hard mask thickness. A chemical mechanical polishing (CMP) step is used to remove excess conductive material (e.g., Cu) overlying an ultra-low-k interlevel dielectric layer (ILD) layer having trenches filled with conductive material, for a damascene interconnect structure. The CMP step proceeds only as far as a liner leaving the oxide hard mask (HM) and the SiCOH HM intact. This insures that the ILD layer remains intact. A Gas Cluster Ion Beam (GCIB) process is used to remove a portion of a liner which is atop a hard mask. Since the GCIB process are highly selective to the material of the liner, the copper remains intact and protrudes above the level of the oxide HM. A wet etch step is used to remove an oxide portion of the hard mask overlying the ILD. The copper and liner protruding above the level of the SiCOH HM remains intact. A final touch-up Cu CMP (CMP) step which chops the protruding liner and Cu patterns off and lands on the SiCOH hard mask follows. In this manner, processes used to remove excess conductive material substantially do not affect the portion of the SiCOH hard mask overlying the interlevel dielectric layer.

The References, Generally

Hu et al. (US 6,660,627 B2) discloses a method for planarization of a semiconductor wafer with high selectivity. The semiconductor wafer has a hard mask 40 over a dielectric layer 38, an organic stop layer 42 disposed on the hard mask. A trench is etched in the dielectric layer and lined with a barrier (liner) 46 that also extends over the stop layer 42. The method includes

performing a first chemical mechanical-polishing (CMP) process to remove the conductor and expose the barrier layer 46. Then a second CMP process is performed to remove the barrier layer 46 and the conductor protruding above the stop layer while exposing the stop layer 42. The second CMP uses a slurry with a chemical composition that is incapable of generating a chemical reaction with the stop layer 42. The polishing selectivity of the barrier layer relative to the stop layer is greater than 50. Since the material of stop layer is different from the material of barrier layer, the high selectivity is easily achieved. Then the stop layer 42 is removed by a third CMP process. At the same time, the conductor and barrier layer above the HM layer are also removed. The polishing selectivity of the stop layer relative to the hard mask layer is greater than 5. Thus, the surface of semiconductor wafer can be highly planarized.

Morrow (US 6,872,666 B2) discloses method for making a dual damascene interconnect using a dual hard mask. Initially, a structure is formed that includes first and second hard masking layers that cover a dielectric layer. A first part of the second hard masking layer and a first part of the first hard masking layer are etched to form an etched region within the hard mask that exposes a first portion of the dielectric layer. That etched region is filled with a sacrificial material. After etching through a second part of the second hard masking layer, the remainder of the sacrificial material is removed prior to subsequent processing.

Ference (6,221,775 B1) discloses a combined chemical mechanical polishing and reactive ion etching process, where CMP is performed with a process and slurry that is selective to the liner, such that the CMP process is stopped after removing all of the excess liner material and produce a protruding plug.

Comments Traversing the Rejection(s)

As described in the specification of the present invention, a damascene interconnect structure comprises:

trenches formed in an ILD defined by openings in a hard mask (HM) overlying the ILD,
a liner which covers the top surface of the HM, and surfaces of the trenches,
damascene material (for example, copper) overfilling the trenches.

The general idea is to remove excess copper.

The HM comprises a first layer of silicon carbide HM material atop the ILD and a second layer of oxide HM on top of the first layer.

The silicon carbide material functions as a polish stop.

The oxide HM material is thick enough to ensure that topographical variations after Cu CMP are entirely within the oxide HM.

Cu CMP is performed, and proceeds only as far as the liner. See FIG. 2.

Next, liner (over the oxide HM) is removed. See FIG. 3. The copper is protruding.

Next, oxide HM is removed. See FIG. 4. The copper and residual liner on the sides of the copper are protruding. The silicon carbide HM is in place.

Finally, a CMP "touch up" process is performed to remove the protruding copper (and residual liner on the sides of the copper). See FIG. 5. The silicon carbide HM is in place.

In Hu (6,660,627), see Figs, 2A-2F, there is

a dielectric layer 38, and

a hard mask 40 is formed on the dielectric layer 38, and a stop layer 42 of an organic polymer is formed on the hard mask 40.

Hu's hard mask 40 is made from typical photoresist material, such as SiO2, SiN, SiON, SiC, SiCO, or SiOCN.

Hu's stop layer 42 is composed of organic polymer material.

In the present invention, the analogous second HM layer is formed of an oxide material.

Via openings 44 are formed. See Fig. 2B. (compare trenches of the present invention).

A barrier layer 46 is deposited. See Fig. 2C. (compare liner of the present invention).

Thereafter, as shown in Fig. 2D, a first chemical mechanical polishing (CMP) process is performed on the conductor for exposing the barrier layer 46 and the via plug 50. Compare present invention, FIG. 2.

Next as shown in Fig. 2E of Hu, a second CMP process is performed on the barrier layer 46 so as to expose the stop layer 42. The mechanism of the second CMP process only requires high polishing selectivity whereby the possibility of delamination of the stop layer 42 can be effectively eliminated.

In a next step according to the present invention , the portion of the liner which is over the hard mask is removed. (The portion of the liner which is within the trench is not affected in this, or in any other step.) This is done using a Gas Cluster Ion Beam (GCIB) process. This process is highly selective to the material of the liner (tantalum, etc.) over the Oxide HM. And, the copper remains substantially intact during this process. The resulting interim (partially completed) interconnect structure is shown in **FIG. 3** wherein it can be observed that the copper from within the trenches protrudes slightly (e.g., substantially equal to the original thickness of the liner), above the level of the Oxide HM. (The "copper line" is slightly higher than the Oxide HM.)

Here the present invention differs from Hu because in Hu, **both** the liner and the copper above the stop layer are removed in the same step. By contrast, in the present invention, the GCIB process only removes the liner and not the copper protruding above the upper HM layer. Moreover, Hu does not teach or suggest the use of the GCIB process.

Next, when the second CMP process of the removal of barrier layer 46 of Hu has been completed, then the stop layer 42 is removed. The stop layer 42 may be removed by a third CMP process. The stop layer 42 may also be removed by a dry etching process or a wet etching

process.

Here again , the present invention differs from Hu.

In the present invention, the Oxide HM is removed, using a suitable process such as hydrogen fluoride (HF) wet etch. The resulting interim (partially completed) interconnect structure is shown in **FIG. 4.** Again, it can be observed that the copper and the liner from within the trenches protrudes slightly. AND, finally, a CMP "touch up" process is performed to remove both the conductive material (e.g., copper) and the liner material protruding from the trenches. See **FIG. 5.**

The problem is that if the hard mask is "just" polished (as in Hu), there can be a problem because chemistry causes a polish rate for copper that is much faster than that for the dielectric. Therefore the copper "wears down" faster than the dielectric. When the copper was "thick" it wasn't such a problem. But now the copper in the circuit pattern is much thinner and the copper wears down too much during the time it takes to wear down the dielectric. This leads to increased resistance and slower chip performance.

The solution to the problem is in the last touch up process.

1) The chemistry for polishing the hard mask can be the same abrasive slurry as in the first (top) layer.

2) The abrasive is non-abrasive or low abrasive

3) the is a low cleaning force of .1-2 psi preferably .2-.5 psi

4) there is no polishing of the hard mask

The claims are amended to clarify the differences, as discussed hereinabove.

step/structure	**HU 6660627**	**Present Invention**
two layers of hard mask	40 carbide 42 polymer	carbide oxide

liner	yes	yes
overfill	yes	yes
Cu CMP to liner	Fig 2D, using CMP-1	FIG 2, using CMP
remove liner to top HM	Fig 2E, using CMP-2 copper is **also** planarized	FIG 3, **GCIB** **copper remains/protrudes**
remove stop layer	Fig 2F, using CMP-3, or dry/wet etch copper is also planarized	FIGs 4 and 5. **two steps.** using wet etch **copper and liner remain and protrude** followed by "touch up" CMP to remove protruding copper and surrounding liner

The first difference between Hu and the present invention, is that when the barrier layer (liner) is removed in Hu (see Fig. 2E) the copper is also removed. In the present invention, the copper is not removed as shown in Figure 3. Also, in Hu, when the stop layer is removed, both the copper and the liner are removed. By contrast, in the present invention, when the top HM is removed, neither the copper nor the liner above the level of the bottom HM are removed, see Figure 4. Therefore, even of Hu were modified by Morrow to replace the organic stop layer of Hu with a HM as taught by Morrow, the resulting structure would still differ because, based on the teachings of Hu because the protruding Cu and surrounding liner would not be removed to the level of the bottom HM as in the present invention as claimed.

In addition, there is no teaching or suggestion in Hu or Morrow of removing Cu and liner projecting above the HM down to the level of the HM.

As noted in the office action, Ference teaches a process and slurry that is selective to the liner, such that the CMP process is stopped after removing all of the excess liner material and produce

a protruding plug. This can be distinguished from the present invention where **both** the liner and the conductor project above the bottom HM and are removed in an additional step.

Accordingly, claim 1 should be held allowable.

Claims 4, 5, 9-11 and 13 depend upon claim 1 and should also be allowable.

Claims 2,3, 6-8, 12 and 14-28 are cancelled.

Conclusion

Applicant respectfully requests that a timely Notice of Allowance be issued in this case.

Respectfully submitted,

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